

TITLE: Microvascular Free Tissue Transfer

SOURCE: Grand Rounds Presentation, UTMB, Dept. of Otolaryngology

DATE: October 20, 2004

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HISTORY

The origins of microvascular surgery can be traced back to Alexis Carrel in the early 1900s. His work illustrated reproducible methods of suturing vessels together with excellent patency rates. Modern microvascular techniques are credited to Jacobsen and Suarez who borrowed the use of the operating microscope from their otologic colleagues, in the 1950s. Human tissue transfer was accomplished as early as 1957 when Som and Seidenberg reconstructed an esophagus with a free jejunal segment. However, this was also the time that regional flaps were coming into use and further microvascular advances were delayed until the 1970s. Multiple reports of free fasciocutaneous flaps entered the literature in 1972, and in 1979 Taylor introduced the composite osteocutaneous groin flap. The late 1980s saw an explosion in free flap reconstruction of mandibular and soft tissue defects, and the use of osseointegrated implants was introduced. From the late 1980s until present, free tissue transfer techniques have become an accepted tool in the reconstruction of head and neck defects.

PREOPERATIVE CONSIDERATIONS

Because of the great technical demand involved in this technique, preoperative planning is a major undertaking that significantly impacts on the success of the procedure. Patient selection, anesthetic planning, donor site selection, and timing of the procedures are all additional concerns in the work-up of a patient who is already preparing to undergo a major head and neck procedure. The viability of the transferred tissue is generally attributed to the technical aspects of microvascular anastomosis; however, errors in patient selection, donor selection, flap-transfer timing, and the geometry of flap inset can all result in flap failure.

There are no absolute indications for free flap reconstruction, and for virtually every instance in which free transfer is used, an argument for a pedicled graft can be made. However, certain defects have proved to be better indications for free transfer. Reconstruction of mandibular defects seem particularly suited to free tissue transfers as do reconstructions that require a thin, pliable tissue such as in the floor-of-mouth. Massive skull base defects present

problems that free flaps seem to solve better than pedicled flaps. Also, because of the potential for neural anastomosis, facial reanimation has recently seen the application of this technology.

There are a number of patient factors that severely limit the likelihood of successful free tissue transfer. Age in and of itself may not be important; however, many serious systemic diseases are more often found in patients of advanced age. Severe cardiovascular disease and atherosclerosis may compromise flap vessels. Diabetes impairs wound healing and negatively affects vessel health. Connective tissue disorders may also compromise the cardiovascular system. Prior irradiation, diabetes (well-controlled), method of anastomosis, timing, vein graft, and specific arteries/veins are not felt to contribute to flap failure rate. The effects of nicotine on flap failure is controversial.

PRINCIPLES OF MICROVASCULAR SURGERY

The techniques used in microvascular surgery are unlike those of conventional surgery. Microvascular surgical skills are usually developed in the microsurgical laboratory on rat vessels. As in all microsurgical procedures, maneuvers must be delicate and accurate. The vascular intima is easily damaged or sent into spasm with excessive traction. Attention to vessel drying is necessary to avoid spasm and thrombosis. Vessels should be constantly bathed in 37 degree centigrade solutions. Excessive vessel cooling is known to induce spasm, as is contact with fresh blood.

Great care is needed when lining the vessels up for anastomosis. The vessels should be adequately mobilized with as pedicles at least 2-3 cm. The greater the mobilization, the easier the anastomosis. Obviously, one wants to avoid any tension at the anastomotic site. But just as important is care in avoiding redundancy in vessel length as this often results in kinking or twisting of vessels. Insetting the flap is undertaken only after the details of the vessel orientation and geometry have been explored and optimized. Failure to address these issues has been shown to negatively affect flap outcome.

The process of microvascular suture is considered to be the most important determinant of vessel patency. Accurate alignment of the intima is of utmost importance. Suture placement must always be symmetrical. Knots must lie flat, and cannot be placed with excessive tension, as intimal damage will result.

The technical and time requirements necessitate a team approach. The resection team does some identification of suitable vasculature, but the reconstruction team will prepare the recipient area. Ideally, this is done while another team is harvesting the donor flap. Although such an approach requires up to 6 surgeons, the procedure moves efficiently and quickly.

END-TO-END ANASTOMOSIS

This technique is used for both arterial and venous anastomosis. The technique is more difficult for veins as the venous walls are thinner and more collapsible. Arterial anastomosis usually require more sutures due to high intraluminal pressures.

End-to-end anastomosis is the most simple, most reliable, and most widely-used method.

To prepare the vessels, 2-3mm of adventitia is stripped from the end of each vessel. This is done with the jeweler's forceps and microscissors under 10 - 16x magnification. This prevents adventitia from being caught in the lumen during anastomoses. The framed approximator clamp is then applied, bringing the two ends of the vessels close enough so that there is little tension during the anastomosis. It is important to remember that the clamps will be flipped after the anterior anastomosis is complete. Blood in the vessel lumen should be flushed, using heparinized saline via a #22 angiocath. Vessel spasm can be reversed with topical lidocaine or gentle dilation (1 ½ times the natural vessel lumen is usually sufficient).

The needle is grasped just beyond its midpoint, 1-2 mm back from the end of the needle holder. Three guide sutures are placed 120 degrees apart, two on the anterior, and one in the posterior wall. The tails are left long. It is imperative that the initial three sutures be accurately placed. Twisting at the anastomoses can result from incorrect suture placement. With the guide sutures in place, an equal number of interrupted sutures are placed between each suture. Enough sutures are placed so that there is no anastomotic leak. Usually a total of 9 sutures are necessary.

Needle placement must be accurate and symmetric. The needle entry point should be twice the thickness of the vessel wall away from the edge. Symmetrical entry should be taken on the opposite edge. Uneven placement leads to vessels overlapping and thrombus. Needle placement should utilize a two-handed action under 20x to 30x magnification. The vessel lumen is cannulated with microforceps (in larger vessels the adventitia is grasped) to provide counter pressure as the needle is placed between. After the needle penetrates the wall, the needle is pulled/pushed through in a circular motion. A two-pass technique is usually used, unless the edges are approximated.

Tying the suture correctly also impacts on the likelihood of vascular patency. Knots are generally tied under 16x magnification. They need to lie flat. The proper amount of tension must be applied each time. Excessive tension damages the vascular intima, inadequate tension hampers the vessel approximation. Surgeons knots are thrown first, followed by a simple square knot. After the anterior wall is sutured, the clamp is flipped, and the process is repeated.

CLAMP RELEASE

Releasing the clamps should be done in the same order each time. Once both anastomoses are completed, the clamp release is begun. The anastomoses are irrigated with a 1% lidocaine solution. The arterial clamp is released first, then the venous. This eliminates misinterpreting venous backflow for adequate arterial inflow. Some leakage will occur, and usually stops with pressure. Brisk bleeding will occasionally occur and requires additional sutures.

VESSEL MISMATCH

Careful placement of sutures can accommodate mismatches of up to a 2:1 lumen. The technique involves placing interrupted sutures farther apart on the larger vessel. When vessel differences between 2:1 to 3:1 occur, beveling or spatulation needed. When beveling an edge, the oblique cut should not be more than 30 degrees. Spatulation involves a longitudinal incision in the cut end of the smaller vessel. When the discrepancy exceeds 3:1, end-to-side anastomoses is

recommended.

END TO SIDE ANASTOMOSIS

As stated above, this method is useful for large vessel mismatches. In order to minimize turbulent flow, the angle of union between donor and recipient should be as small as possible. Angles less than 60 degrees are usually acceptable. The angle of anastomosis can be decreased by spatulating or beveling. To prepare the recipient vessel, an elliptical excision in the wall is made. Unlike the end to end technique, there are only two guide sutures, each placed 180 degrees apart. The intervening sutures are placed as usual.

CONTINUOUS SUTURE TECHNIQUE

The major advantage of this technique is that it is faster and associated with less anastomotic leakage (50% faster). However, it significantly narrows the vessel lumen. As a result, vessels less than 2.5mm in diameter respond poorly to this method. The main application is for end to side anastomoses on large veins.

INTERPOSITIONAL VEIN GRAFTS

This adjunctive technique is required when the vascular pedicles do not approximate without tension. The donor vein is most commonly obtained from the saphenous. When aligning the vessels for arterial anastomoses, the vein grafts must be reversed so that valves do not obstruct flow. This is not necessary for the venous system. Placement of a free suture through the distal end of the vein serves to orient the vessels. Vein grafts have been traditionally associated with poorer outcomes, though the more recent literature shows the use of vein grafts has no significant effect on flap outcomes.

MECHANICAL AIDS

Over the years, multiple alternative methodologies have been proposed to obviate the need for hand-sewing anastomoses. Some have been more successful than others, with devices such as the coupling device entering mainstream practice. The most commonly reported forms of mechanical anastomosis utilize either barbed polyethylene rings or metal clips to approximate vessel ends. These systems are reported to result in total vessel intima version with little or no intraluminal foreign material or exposed vessel wall collagen. Laser “welding” anastomosis has also been reported. The coupling devices have been shown to increase consistency, speed (with a concomitant decrease in ischemia time), and ease of use in areas with difficult exposure. Patency rates at least match hand-sewn vessels. These devices can be used for both end-to-end anastomoses and end-to-side anastomoses. The only limitation appears to be in connection with the arterial anastomosis. An increased arterial thrombosis rate was seen when coupling devices were used. This correlates with the increased difficulty in using these devices with thick-walled vessels. Thus, many surgeons will use the coupling devices for anastomosing the venous system after hand-sewing the artery.

ISCHEMIA TIMES

Ischemia time is the amount of time that passes between when the donor vessels are ligated and when the clamps are removed after anastomosis in the head and neck. It is generally felt that decreasing ischemia time improves a flap's chances for success. Experimental data indicate that ischemia time of greater than 4 hours may contribute to increased flap failure. For this reason, flaps are often contoured and plated at the harvest site before ligation of donor vessels. Insetting of the flap is done before beginning vascular anastomosis with special attention given to position of the pedicle and vessel geometry. Deep or awkward suturing necessary for inseting is performed before the pedicle is reanastomosed in order to avoid injury to flap vessels.

PATENCY AND PREVENTING THROMBOSIS

Patency of an anastomosis can be tested in a variety of ways. Venous patency is easily evident when the vessel is translucent. Direct observation of expansive pulsation is a reliable indicator of patency, whereas longitudinal pulsation usually portends partial or complete obstruction. The most reliable test is the intraoperative Doppler Ultrasound Flowmeter.

As stated previously, the chance of thromboses is greatest at the site of anastomoses 15 to 20 minutes following the closure. It is therefore customary to observe the anastomosis and test its patency during this period of time. If partial obstruction occurs, gently squeezing the vessel with forceps, or massaging the vessel may break up the thrombus. A complete thromboses necessitates resection of the damaged area, and repeat anastomoses.

Vascular thrombosis is most commonly due to technical error in suture placement, or the use of a vessel with damaged intima. Venous rather than arterial thrombosis is the most common cause of flap failure. The thinner venous wall makes the anastomosis more fragile, more compressible, and more likely to twist and kink. After the first 20 minutes, the next critical period is postoperative days 1 - 3. In most cases, a flap that is successful at day 5, will not thrombose. However, the vascular pedicle cannot be safely divided for at least 8 days.

CONSIDERATIONS IN FLAP INSETTING

In head and reconstruction recipient vessels can include the facial artery, superior thyroid artery, or any branches of the external carotid artery. Also available are the transverse cervical and external carotid artery itself. The external jugular vein, common facial vein (or any other large contributing vessel to the internal jugular system), and internal jugular vein are commonly used vessels for venous anastomosis. Again, the transverse cervical can be used, as well as vessels with retrograde flow (superficial temporal). Venous end-to-side anastomosis is often performed using the internal jugular vein with care taken to keep the angle of vessel confluence at 60 degrees or less (felt to decrease turbid flow). Arterial end-to-side may be performed with the common or internal carotid arteries as a last resort. This is contraindicated in patients who have undergone radiation therapy due to the very high risk of atherosclerotic plaques in these vessels.

Flap geometry has been demonstrated in some studies to be an important determinant of

flap survival. In retrospective reviews, experienced surgeons have noted problems with flap circulation due exclusively to poor choice of flap geometry. Before the anastomosis is begun, one must visualize how the flap will be inset to ensure an ideal path for the pedicle. Lack of attention to these details may result in vessel kinking and subsequent thrombosis. The most favorable geometry allows for the vessels to lie longitudinally in the neck without tension or kinking.

POSTOPERATIVE CARE

Proper care after the surgery requires personnel who understand the basic principles of free flap reconstruction. Pressure in the vicinity of the pedicle is avoided. Such pressure may come in the form of tracheotomy ties or dressings. It must also be pointed out that supplemental oxygen, or humidified air can cool a superficial flap and inhibit its blood flow. Strict orders to keep the head in a neutral position are important in order to limit the tension placed on the anastomosis.

Hemodynamics and blood volume must be monitored closely. Although scant scientific evidence exists to support an ideal hematocrit in postoperative free flap patients, the consensus among experienced surgeons appears to be somewhere between 27 and 29. It is important to inform the ICU personnel to avoid transfusing these patients without notifying the surgeon. Close surveillance for hematoma formation is necessary to avoid the deadly consequences of vascular compression. Blood pressure should be maintained appropriately.

Pharmacotherapy has become a routine in free tissue transfers, and much of the basis is borrowed from organ transplantation data. Aspirin therapy is initiated after the surgery using 5 - 10 grains daily for 2 to 3 weeks in order to inhibit platelet and endothelial cyclooxygenase. Dextran infusion has also been used for its viscosity-lowering properties and inhibition of rouleaux formation. Despite these properties, studies show no effect on overall flap survival when compared with aspirin. Systemic complications are 3.9-7.2 times more common with dextran infusion. Heparin administration, whether in the form of a 5000U one-time bolus at the time of release of the anastomosis, or as a post-operative drip has little clinical data to support its use. Recently, low-molecular weight heparin has been shown to reduce thrombosis in renal grafts. Other anticoagulation agents have yet to be evaluated in any large studies.

8-20% of patients undergoing free tissue transfer will develop an infection. The effects of post-operative infection can be serious in the area of a free flap anastomosis. This concern has led to several studies looking at the efficacy of different antibiotic regimes. Prolonged Clindamycin (5 days vs 1) was not shown to effect flap outcome. Topical antibiotics used during the surgical procedure also showed no influence on flap outcome. The literature supports using intravenous antibiotics administered in a fashion similar to other major head and neck procedures. Delirium tremens prophylaxis is also often necessary in this patient population.

POSTOPERATIVE MONITORING

Although many different methods exist, the current standard is clinical evaluation. This is accomplished by visually inspecting flap color, turgor and capillary refill; using the hand-held Doppler to evaluate the pedicle frequently during the first 3 days; and performing the prick test

daily. A healthy flap will be pink, warm, minimally edematous, and will have a capillary refill time of 1 - 3 seconds. The prick test will produce 1 to 3 drops of bright red blood. Venous occlusion is indicated by bluish, edematous flap and brisk, dark bleeding on the prick test. Arterial problems produce a pale, cold, flap with no bleeding after pricking.

Early detection of flap compromise allows for earlier intervention, and improved survival. This has led to the development of many different methods of monitoring. Implantable dopplers and flow dopplers have been explored. Temperature measurements have demonstrated reliability, although interference from ambient temperatures in the oral cavity can confound data. Others have used near infra-red spectroscopy to monitor the concentrations of oxy and deoxyhemoglobin. Animal studies indicate accurate measurements through as much as 10cm of tissue. Transcutaneous and intravascular devices which measure oxygen tension have seen some enthusiasm, but expense continues to be an obstacle. The laser doppler flowmeter also holds promise, but is not applicable to deep flaps or those in the oral cavity. As in many cases in medicine, multiple different solutions to a problem indicate lack of a good solution. Clinical assessment will remain the standard until the expense and reliability problems of the others improve.

TREATMENT OF VASCULAR COMPROMISE

Early detection remains the key to successful salvage. As stated, the second critical period occurs during postoperative days 1 - 3. Venous thrombosis is the most common etiology of flap failure. Most studies indicate that exploration within the first 1 - 2 hours of detection yield the best salvage rates. Success rates fall off dramatically after 8 hours of occlusion. Aggressive exploration can increase the survival rates by up to 10%.

Once the patient is returned to the operating room, the flap is quickly dismantled and the anastomosis examined. Extrinsic pressure from hematoma formation, kinking, or twisting is addressed first. Unless successful, the next step is takedown of the anastomosis. Once this is accomplished, the flap vessels are irrigated with heparinized saline, and the anastomosis is repeated. Failure of free irrigation indicates a long standing thrombosis in the microvasculature. Plasminogen activators such as strepto and urokinase, and recombinant tissue plasminogen activator (TPA) have been used successfully in such instances. These are applied with the venous drainage from the flap disconnected, to avoid systemic doses. This allows high concentrations of the drug. Once free irrigation is accomplished, the anastomoses are performed in the usual manner.

Microvascular free tissue transfer can be a highly successful method of addressing tissue defects after head and neck ablative surgery. The basic principles of microvascular surgery have been refined over the past thirty years. Still, there is little data to support many practices which have become routine in free tissue transfer. This is an area of otolaryngology—head & neck surgery which is ripe for discovery.

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